Influences of Affective Stimulus and Placement on Procedural Task Learning and Performance

A Thesis

SUBMITTED TO THE FACULTY OF THE

UNIVERSITY OF MINNESOTA

BY

Samuel A. Birkholz

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

MASTER OF ARTS

Eric E. Hessler, Ph.D., Advisor

Aydin Durgunoglu, Ph.D., Committee member

Jung Eun Lee, Ph.D., Committee member

June 2019

Abstract

Recall of words (Yang, Yang, & Isen, 2013) and image recognition (Flaisch, Steinhauser, & Schupp, 2016) is influenced by affect. This study addresses generalizability of those effects by testing how affect and stimuli placement influence procedural memory. Participants (*n* = 78) completed one of four conditions where a monetary gift was either unexpectedly received or not received, and where the gift was given either before or after learning the Tower of Hanoi. Participants completed the Positive and Negative Affect Schedule Expanded Form (PANAS) to measure affective tone. Attentiveness was higher after learning than before while fatigue was lower after learning than before. Researchers assessed Tower of Hanoi practice performance with results suggesting positive affect groups' completion times improved over subsequent practice trials. Exploratory analysis using the rate of change in practice trial completion time indicated positive affect groups learned at a faster rate. No differences manifested between groups' pre-test, post-test, or transfer test completion times. Results are partially explained by existing theory regarding the role of emotion in declarative memory systems. Affect is linked to faster and stronger recall in episodic memory (Dolan, 2016) and worsened performance in picture recognition (Flaisch et al., 2016). However other mechanisms like negative affect, motivation, and attention still need to be explored (Chun & Turk-Browne, 2007; Flaisch et al., 2016; Moore et al., 2014). The current study suggests affect does not influence procedural learning and performance similar to declarative memory systems. More research is needed to identify similarities and differences between memory systems.

Keywords: procedural learning, perceptual-motor model, affect, stimulus placement, attention

Table of Contents

List of Figures

Influences of Affective Stimulus and Placement on Procedural Task Learning and Performance

Learning can be influenced by changes in affective tone and the placement of an affective stimulus (Flaisch, Steinhauser, & Schupp, 2016; Yang, Yang, & Isen, 2013). Affective tone is defined as a temporary state of emotion or feeling. For example, when a target image is proximal in space or time to positive affective inducing images, memory for the target image is increased. This effect can be seen regardless of the affective image being placed before or after the target image (Flaisch et al., 2016). Comparable results have been observed in semantic and word-based recall (Yang et al., 2013), and mathematical equation learning and problem solving (Moore, Rudig, & Ashcraft, 2014), but have not been addressed within the system of procedural memory task performance (Birkholz, Hessler, & Root, 2016). The purpose of this study is to test the generalizability of enhancement theories, previously not examined regarding procedural learning and memory testing.

Theory regarding memory functions has changed over time, suggesting learning and memory processes have yet to be fully understood (Atkinson & Shiffrin, 1968; Baddeley, 2000; Baddeley & Hitch, 1974). Atkinson and Shiffrin (1968) suggested a multi-store model of memory, where a stimulus first enters as sensory information, is processed and interpreted in short-term memory, then is transferred into long-term memory if practiced enough. Atkinson and Shiffrin (1968) stated a process of recall must occur to interpret sensory information or simply remember previously learned information. Baddeley and Hitch (1974) expanded on the idea of short-term memory by adding a new process called working memory. Within working memory is a mechanism called the visuospatial sketchpad, where both visual and spatial information is maintained and can be quickly recalled (Baddeley & Hitch, 1974). Baddeley (2000) added the episodic buffer, which is responsible for processing events or strings of actions, over a brief period.

Procedural memories, like riding a bike or tying shoelaces, are memories about how to perform a specific string of actions to achieve a desired result. These types of memories not only follow the pathways outlined by the multi-store model and working memory model, but also pass through three stages along the way: (a) cognitive phase, (b) associative phase, and (c) autonomous phase (Fitts, 1964). The cognitive phase is when an individual is first introduced to a novel task and must discover the goal. The associative phase incorporates increased cognitive processing with motor movements to learn single steps; piecing them together into a complete process. The autonomous phase requires less cognitive processing and is marked by fluid motor movements. In the final stage a procedure has become more automatic, often allowing for the procedure to be carried out while the person engages in other non-conflicting activities. An individual can talk and perform procedural skills but would find it difficult to perform conflicting motor tasks (e.g., circling the right leg clockwise while tracing the number 6 with the right hand).

Research indicates procedural memory is dissimilar from explicit episodic memory or memory of specific events (Cohen, Eichenbaum, Deacedo, & Corkin, 1985; Xu & Corkin, 2001). Henry Molaison (H. M.), a participant in many case studies involving memory due to undergoing a bilateral medial temporal lobectomy to remove most of his hippocampus (Scoville & Milner, 1957). H. M. learned the procedure necessary to complete the Tower of Hanoi but could not explicitly recall ever going through the process of learning it. From this we can see these distinct memory systems are associated with different anatomical structures (Cohen et al., 1985). Factors influencing learning and memory formation may act on one system (episodic memory) but not another (procedural memory). This means factors believed to influence memory in general need to be tested on both types of memory systems.

Emotion, commonly referred to as affect, can enhance and interfere with memory (Flaisch et al., 2016; Yang et al., 2013). Research suggests differences in affective tone directly impact memory by acting on short-term memory and working memory capacity (Yang et al., 2013). Researchers compared participants who received an unexpected gift before memory testing to control participants who did not receive the gift until completing the study Researchers used a word-span task requiring participants to memorize a list of words, then recall as many as possible from the list, to measure short-term memory. An operation-span task requiring a person to solve simple mathematical problems and read a word after each problem, then recall the words later, was used to measure working memory. Results indicated positive affect significantly increased working memory capacity compared to a neutral control group (Yang et al., 2013).

Flaisch et al. (2016) demonstrated the influence of positive affect by utilizing affect inducing images. Participants viewed a string of images where sometimes neutral target images were preceded by, immediately followed by, or preceded and immediately followed by emotionally charged images (Flaisch et al., 2016). Results indicated memory for neutral target images was worse when the target images were proximal to either positive or negative affect inducing images than when proximal to other neutral images (Flaisch et al., 2016). Therefore exposure to emotionally charged stimuli immediately following target material may prevent target material from being consolidated. Results from Flaisch et al. (2016) highlight points iterated by Squire (1986) regarding the importance of the consolidation process. Flaisch et al. (2016) also lends support to the idea different memory systems are influenced by affect differently by contradicting the performance enhancement observed by Yang et al. (2013).

Researchers have measured memory in the form of retention performance to test the effects of emotion on the learning of procedural memory tasks (Roediger, 1990). Retention refers to the ability of a person to recall or retain information obtained through learning experiences. Retention is interpreted on a continuous interval and is often measured per trial by recording total number of correct responses, incorrect responses, reaction time, or completion time (Roediger, 1990). Each measure of retention captures the proficiency of recall at a given point in time. Recall is a memory retrieval process by which information is brought back into short-term memory from long-term memory or by which information held in working memory is recognized.

Procedural memories are a mixture of long-term memory and working memory, thus testing recall and transfer would better enable interpretation of learning and memory retention (Moore et al., 2014). Transfer of knowledge is demonstrated by the ability to complete a similar task based off learning of an initial task or apply learned information to a novel yet similar concept. An example of testing transfer within procedural memory task performance can be explained using the Tower of Hanoi. The procedure for most efficient completion of the Tower of Hanoi changes as the number of discs change. This means a tower with 3 discs may not only be easier than a tower with 4 discs, but the move sequence itself changes. Successful completion then depends on long-term memory and the manipulation of previously learned information in working memory.

Learning to complete a procedural puzzle, such as the Tower of Hanoi, requires progressing through the cognitive phase, associative phase, and autonomous phase (Fitts, 1964). These phases are unique to procedural memory and differentiate it as a different memory system separate from explicit memory (Cohen et al., 1985; Xu & Corkin, 2001). The explicit memory learning process can be directly affected by the internal variable of emotion, which can be influenced by external stimuli (Moore et al., 2014; Yang et al., 2013), yet comparable results have not been replicated with procedural memory.

The purpose of this study is to test current theories regarding affect against a different form of memory; procedural memory. This research proposes four hypotheses positive affect induced prior to learning should enhance (a) pre-test Tower of Hanoi performance as compared to all other groups, (b) post-test Tower of Hanoi performance as compared to all other groups, and (c) transfer performance as compared to all other groups, whereas (d) positive affect induced after learning should not influence subsequent Tower of Hanoi test and transfer performance. Support of the four hypotheses would suggest support of a metahypothesis that affective tone influences procedural learning and performance similar to declarative memory systems. Performance increases can be attributed to changes in affective tone due to the unexpected reward (Yang et al., 2013).

Method

Participants

Seventy-eight participants (33 men, 45 women; 18-24 years of age) were recruited. Participants received General Psychology course credit and a $10 Amazon.com gift card for participation. Data from two participants were removed after the manipulation check analysis due to worsening completion times during practice. Data from another participant was removed due to incomplete data collected. All participants were treated in accordance with the ethical principles of the American Psychological Association.

Materials

The Tower of Hanoi (see Figure 1) requires participants to move a tower of discs from a start peg to a target peg. There are two rules for moving the discs: (a) only one disc can be moved at a time and (b) a larger disc cannot be placed on top of a smaller disc. The Tower of Hanoi typically consists of three discs and three pegs, with difficulty increasing as more discs are added. Researchers measured retention using the standard Tower of Hanoi arrangement with three pegs and three discs while a transfer task used a slightly more difficult version consisting of three pegs and four discs.

The Positive and Negative Affect Schedule Expanded Form (PANAS; see Appendix A; Watson, Clark, & Tellegen, 1999) measured self-reported state affect during the experiment. Participants rated to what extent they agreed with a given statement with either positive or negative connotations, then these responses were compiled into a numerical representation of the participant's affect state. Higher scores on either positive affect words or negative affect words correspond to either higher positive affective tone or higher negative affective tone respectively. Within the general dimension portion 10 responses were coded general positive affective words while 10 others were coded general negative affective words. Other positive and negative emotionally charged words were broken into subgroups and categorized to analyze the following dependent variables: General positive, general negative, joviality, attentiveness, sadness, fatigue, and surprise. These subgroups were identified logically as pertinent to this study while other subgroups such as fear, hostility, and shyness were excluded.

Procedure

One control group first completed the PANAS. Next, these participants were taught how to complete the 3-disc Tower of Hanoi puzzle with verbal, written, and visual instructions. Written instructions were read aloud and given to each participant briefly outlining the objective and rules of the task. Visual instructions were provided in the form of one researcher demonstration.

After instruction all participants were allowed 5 minutes to practice the Tower of Hanoi. The number of practice trials and successful completions during practice were recorded. Successfully completing the puzzle or restarting marked beginning a new practice trial. Initial test performance on the Tower of Hanoi puzzle was measured in seconds and out of sight of the participant. Immediately following learning the Tower of Hanoi, and initial testing, participants were asked to read a psychology magazine for five minutes. Immediately following the 5-minute period, participants were retested on Tower of Hanoi puzzle performance. Following the second testing phase, transfer was tested using the 4-disc version of the Tower of Hanoi with no instruction. After the transfer measure, participants were awarded a $10.00 Amazon.com gift card. Another control group followed a similar process except they did not complete PANAS prior to learning the Tower of Hanoi. Instead, participants in this group were instructed to complete the PANAS after learning in lieu of a 5-minute waiting period.

One experimental group followed the same process as the first control group except participants were awarded a $10.00 Amazon.com gift card prior to completing the PANAS. A second experimental group followed the same process as the second control group except participants were awarded a $10.00 Amazon.com gift card prior to completing the PANAS (see Figure 2).

Results

PANAS

A series of 2 (Affect: positive, neutral) x 2 (Placement: before learning, after learning) independent groups analyses of variance (ANOVA) were used to examine the following dependent variables: General positive, general negative, joviality, attentiveness, sadness, fatigue, and surprise. Results indicated a significant main effect of Placement on attentiveness, $F(1, 74) = 6.05$, $p < .05$, $\eta_p^2 = .08$ (see Figure 3). Attentiveness was higher after learning ($M = 14.91$, $SD = 3.36$) than before learning ($M = 13.22$, $SD = 2.58$). There was also a significant main effect of Placement on fatigue, F(1,

74) = 3.96, $p = .05$, $\eta_p^2 = .05$ (see Figure 4). Fatigue was lower after learning ($M = 8.19$, $SD = 3.74$) than before learning ($M = 10.00$, $SD = 3.96$).

Practice

Each participant was required to complete at least two of the practice trials being analyzed in order for their data to be included in the practice trial analyses. Ten participants were excluded from all of the practice trial analyses (three participants excluded from control group one, three from experimental group one, and four from experimental group two).

A 2 (Affect) x 2 (Placement) x 2 (Practice: practice two, practice three) mixed ANOVA was conducted to examine completion time differences between practice trials and across conditions. There was a significant main effect of Practice on completion time, $F(1, 60) = 5.38$, $p < .05$, $\eta_p^2 = .08$. There was also a significant Affect by Practice interaction, $F(1, 60) = 4.46$, $p < .05$, $\eta_p^2 = .07$ (see Figure 5). No other main effects or interactions were significant. Simple comparisons were conducted to follow-up the significant Affect by Practice interaction. Results indicated positive groups' times differed significantly from one practice trial to the other $F(1, 62) = 11.05$, $p < .01$, $r = .39$, with practice three ($M = 16.05$, $SD = 4.53$) being faster than practice two ($M = 20.42$, $SD = 12.17$; see Figure 5). No other simple comparisons were significant.

Researchers calculated a power curve equation for each participant's practice period. The derivative of each equation was taken and solved at the points equal to the second, third, and fourth practice trial times. These derivatives gave the rate of change for each participant's power curve at each point. The rates of change were analyzed using a 3

(Practice: practice two, practice three, practice four) x 2 (Affect) x 2 (Placement) mixed ANOVA to examine changes in completion time (s). The main effect of Affect, $F(1, 70) = 3.91$, $p = .05$, $\eta_p^2 = 0.05$, and Practice, $F(2, 140) = 8.43$, $p < .001$, $\eta_p^2 = 0.11$, on rate of change were both significant. The rate at which practice completion times changed was higher for positive groups ($M = 0.50$, $SD = 0.15$) than neutral groups ($M = 0.07$, $SD = 0.16$). Pairwise comparisons for the main effect of Practice indicated changes in completion time differed between practice two and practice three ($p < .05$), practice two and practice four ($p < .05$), and practice three and practice four ($p < .05$). Respectively practice two completion times changed fastest ($M = 0.49$, $SD = 0.18$), then practice three ($M = 0.22$, $SD = 0.09$), and practice four ($M = 0.14$, $SD = 0.06$). There was also a significant Affect by Practice interaction, $F(1, 140) = 3.90$, $p < .05$, $\eta_p^2 = .05$. No other main effects or interactions were significant.

A simple comparisons analysis was used to follow-up the significant Affect by Practice interaction. Results indicated a significant difference between Practice within the positive conditions, $F(1, 72) = 10.91$, $p < .01$, $r = .35$, with practice two being greatest ($M = 0.84$, $SD = 1.10$), followed by practice three ($M = 0.40$, $SD = 0.54$) then practice four ($M = 0.26$, $SD = 0.36$; see Figure 6). Simple comparisons were not significant for the neutral conditions.

Simple comparisons at each level of Practice indicated significant differences between groups at practice two, $F(1, 70) = 3.90$, $p = .05$, $r = .23$, practice three, $F(1, 70) = 3.91$, $p = .05$, $r = .23$, and practice four, $F(1, 70) = 3.91$, $p = .05$, $r = .23$ (see Figure 6). Positive groups had higher rates of change than neutral groups at practice two ($M = 0.14$, *SD* = 1.88), practice three (*M* = 0.05, *SD* = 0.94), and practice four (*M* = 0.03, *SD* = 0.63).

A 2 (Affect) x 2 (Placement) independent groups ANOVA was used to examine potential differences in the number of attempted practice trials between groups. Neither the main effect of Affect, $F(1, 70) = 0.32$, $p = .58$, $\eta_p^2 = .01$, nor Placement, $F(1, 70) = 3.46$, $p = .07$, $\eta_p^2 = .05$, on number of attempted practice trials were significant. The Affect by Placement interaction was not significant, $F(1, 70) = 5.53$, $p = .68$, $\eta_p^2 < .01$.

Test and Transfer

A 2 (Affect) x 2 (Placement) x 2 (Timed Trial: first test, second test) mixed ANOVA was used to examine differences in performance between conditions and across timed trials. Completion time (s) data was transformed using a natural log (LN) transformation to reduce heteroskedasticity. Homogeneity of variance was not violated for LN first test ($p = .88$) or LN second test ($p = .94$). There were no significant main effects or interactions. A 2 (Affect) x 2 (Placement) independent groups ANOVA was used to examine the dependent variable of transfer time. Transfer test completion time was also transformed using a LN transformation. There were no significant effects.

Discussion

This study aimed to determine if positive affective stimuli influenced procedural task learning and performance. Previous research suggests positive affect enhances working memory and short-term memory (Yang et al., 2013) while the current study suggests increased attentiveness and decreased fatigue enhances procedural skill learning. Future research should address specific factors like motivation and attention due to similarities in memory models and differences in anatomical structures responsible for procedural learning and performance (Baddeley & Hitch, 1974; Fitts, 1964; Xu & Corkin, 2001). After reviewing the literature, four hypotheses and a metahypothesis were formed and tested. Researchers expected increased positive affect to enhance Tower of Hanoi performance at test and transfer when induced prior to learning the Tower of Hanoi with no observable affects occurring when induced after learning. This would suggest affect influences procedural task learning and performance similar to declarative memory systems.

These hypotheses and the metahypothesis were not directly supported but there were positive effects within the learning process. Individuals who received an unexpected gift card before practice demonstrated faster improvements over repeated rehearsals of the Tower of Hanoi compared to those who did not receive a gift until completion of the study. This means fewer practice trials were needed to achieve mastery of the puzzle. These results are congruent with findings stating working memory is enhanced by positive affective tone (Yang et al., 2013). The cognitive and associative phases of perceptual-motor learning are closely related to working memory outlined in current models (Fitts, 1964; Baddeley & Hitch, 1974). Working memory, similar to the cognitive and associative stages defined by Fitts (1964), is marked by increased use of cognitive resources. Although congruent with similar research, these exploratory results should be replicated for consistency.

An important finding of this study illustrates how affect changes when learning novel procedural tasks. Self-reported attentiveness increased over the course of learning while fatigue decreased. These affective changes may be due to receiving an unexpected gift card, but other factors could have played a role. Most research focuses on how happiness improves learning and memory function (Moore et al., 2014; Yang et al., 2013) but learning to complete a new task or completing a task successfully may be related to self-efficacy or stem from motivational influences. Self-efficacy is a person's belief regarding their ability to perform a desired action, and higher self-efficacy translates into less negative affect (Bandura, 2010). Self-efficacy was not measured in this study but being able to successfully learn and repeatedly complete the Tower of Hanoi puzzle may have boosted self-efficacy enough to indirectly increase attentiveness or lower fatigue. Future research focused on how the act of learning new skills influences affect should account for changes in self-efficacy to determine if changes occur and if they can be linked to specific affective dimensions.

Results of the current study can partially explain affective influence similarities between declarative and procedural memory systems. Increases in self-reported attentiveness paired with decreased fatigue appears to lessen the amount of time or rehearsals needed to learn novel procedural tasks. Similar effects are observed in research involving emotionally charged episodic memories (Dolan, 2002). Episodic memories, or memories for specific events, tied to emotional responses like happiness are recalled faster and more strongly than neutral memories (Dolan, 2002). Dolan (2002) also stated recall for episodic memories is better when tied to negative emotions. Negative affect was not examined in the current study and future research should address negative affect to determine if effects on procedural memory learning and testing exist. Flaisch et al.

(2016) illustrated how negative emotional images hinder memory for target images. It is possible negative affective tone induced prior to learning could decrease the rate people learn the Tower of Hanoi.

Positive affect induced prior to learning is not the only possible explanation for improvements in learning. One positive affect group did not receive their unexpected reward until after learning yet they exhibited increased rates of learning. It is possible completing fewer requirements prior to learning the Tower of Hanoi uses less cognitive resources and allows for increased cognitive processing of the task. Cognitive load is described as the amount of cognitive resources devoted to completing a task (Sweller, 1988). When we use working memory, our cognitive load increases leaving less resources for other information. Less capacity for processing the rules and requirements for completing the Tower of Hanoi may directly hinder the cognitive and associative phases outlined by Fitts (1964). This explanation allows for crossover between working-memory models and task acquisition models. The cognitive and associative phases outlined by Fitts (1964) are described similar to more modern understanding of working memory. During the cognitive and associative phases a person must continuously rehearse the goals, rules, and individual steps of a task. Therefore we may assume factors influencing working memory will also act on early stages of procedural task learning.

Other potential factors such as motivation have been implicated as an actor in the learning and memory processes (Moore et al., 2014; Krawczyk & D'esposito, 2013) but still need to be researched regarding perceptual-motor learning. Motivation is a theoretical construct which helps explain internal and external desires or drives to act in specific ways (Elliot & Covington, 2001). Previous researchers have shown learning can be directly affected by differing levels of motivation (Krawczyk & D'esposito, 2013; Moore et al., 2014). The potential of a positive outcome such as gratification or monetary compensation produces motivation to perform well. Krawczyk and D'esposito (2013) demonstrated cognitive efficiency and performance are affected by motivation, especially when monetary incentives are introduced. Moore et al. (2014) also explained motivation and working memory are important to understanding how students acquire procedural skills. Higher levels of motivation result in higher levels of performance, but individual differences concerning the type of motivation involved can also affect final performance (Moore et al., 2014). Motivation can be split into two distinct categories called intrinsic and extrinsic (Ryan & Deci, 2000). Intrinsic motivation can be defined as motivation or drive to perform an action based on inherent or internal satisfaction (Ryan & Deci, 2000), such as learning how to complete a complex puzzle like the Tower of Hanoi because it is interesting or, because it is fun. In contrast extrinsic motivation is the drive or desire to complete a task because there is a reward, or outside pressure to perform (Ryan & Deci, 2000). Future research designs focused on learning and memory should account for motivation as a potential influence.

In addition to motivation and self-efficacy, future research should focus on the role attention plays in procedural skill learning. The current study demonstrates how increased self-reported attentiveness results in improved learning rates. Learning cannot occur without attention in some form (Chun & Turk-Browne, 2007). As an individual transitions through the three phases of perceptual-motor skill learning, the cognitive resources devoted to spatial attention might change. Similarly, the amount of cognitive resources spent on visual processing might change. When we perceive familiar stimuli like faces of friends and family less attention is devoted to deciphering the images (Chun & Turk-Browne, 2007). If similar declines in attention do occur over repeated rehearsals of procedural tasks other topics like divided, selective, and alternating attention could be explored.

This study used a $10 Amazon.com gift card which appeared to be ineffective for producing higher scores in the general positive, joviality, and surprise PANAS subgroups. Yang et al. (2013) gave candy to participants and reports increased positive affect. The current study's use of a gift card resulted in positive affect groups not differing from the neutral groups except for in the areas of attentiveness and fatigue. Future research using positive affective tone induction techniques should consider the possibility of limited manipulation impact to ensure the manipulation has a desired effect. Participants in this study only reported being more attentive and less fatigued after learning how to complete the Tower of Hanoi. Previous research has utilized candy as a form of positive affective tone induction (Yang et al., 2013) while some studies focusing on the effectiveness of affective tone induction techniques have utilized images and music (Flaisch et al., 2016; Zhang, Yu, & Barrett, 2014). The gift card did not lower scores in the general negative and sadness PANAS subgroups either. Alternate affective tone induction techniques may be more effective and yield different overall study results.

Results can be applied to procedural learning theory development. Memory models such as Baddeley's model of working memory (Baddeley & Hitch, 1974), and learning theories involving perceptual-motor skill learning can be revisited from new perspectives. One overall goal should be building a better understanding of procedural learning and memory as a unique process with factors such as affective tone having both similar and different effects as compared to those observed in semantic memory research. Future research can build on this study by testing effect boundaries and expanding understanding of memory systems' overlap and discontinuity.

Until more evidence is uncovered, researchers and educators should be careful to consider memory systems as unique and apart from each other. Factors like affect, motivation, and attention should not be assumed to influence every memory system in similar ways. Fitts (1964) outlined the cognitive, associative, and autonomous phases of perceptual-motor skill learning as unique to the procedural memory system. Once an individual reaches the level of autonomy or mastery, influences acting on the learning process might not matter. This study shows how receipt of an unexpected gift card affects learning but clearly demonstrates no differences in test and transfer performance. The results may change with a larger sample or a different affective tone induction method, but there is a chance this study captured the true nature of procedural memory learning and testing when positive affective tone is manipulated.

Our understanding of learning and memory is not nearly complete and procedural memory may be the least understood of all (Birkholz et al., 2016). Research has focused on more explicit functions like word recall (Yang et al., 2013) and picture recognition (Flaisch et al., 2016) while not examining more implicit forms of memory. Exploratory analyses of this study allow for further insight into how increased attentiveness and decreased fatigue influence the cognitive and associative phases of perceptual-motor learning. As researchers continue examining the underlying mechanisms of learning and memory, understanding moderating and mediating factors becomes increasingly important.

Figure 1. The Tower of Hanoi is a wooden puzzle requiring a stack of discs to be moved one by one from the start peg on the left to the target peg on the right. Participants must follow two rules: (a) only one disc can be moved at a time, and (b) a larger disc cannot be placed atop a smaller disc. Two more goals of the puzzle are to complete it as quickly as possible and by making as few moves as possible. The four-disc version is pictured here.

C1: PANAS→Learning→Pre-test→Waiting→Post-test→Transfer

C2: Learning→Pre-test→PANAS→Post-test→Transfer

E1: Unexpected Reward→PANAS→Learning→Pre-test→Waiting→Post-test→Transfer

E2: Learning→Pre-test→Unexpected Reward→PANAS→Post-test→Transfer

Figure 2. Procedure for each group respectively highlighting differences in placement and affective tone.

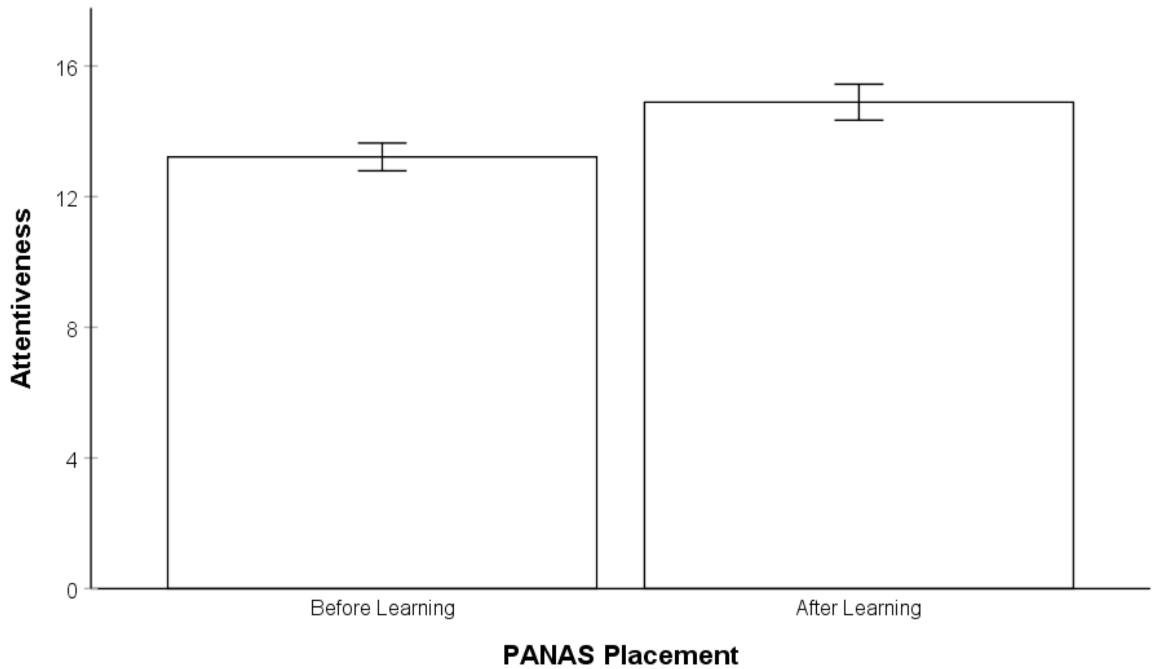

Figure 3. Self-reported attentiveness measured before and after learning the Tower of Hanoi. Error bars denote one standard error around each mean.

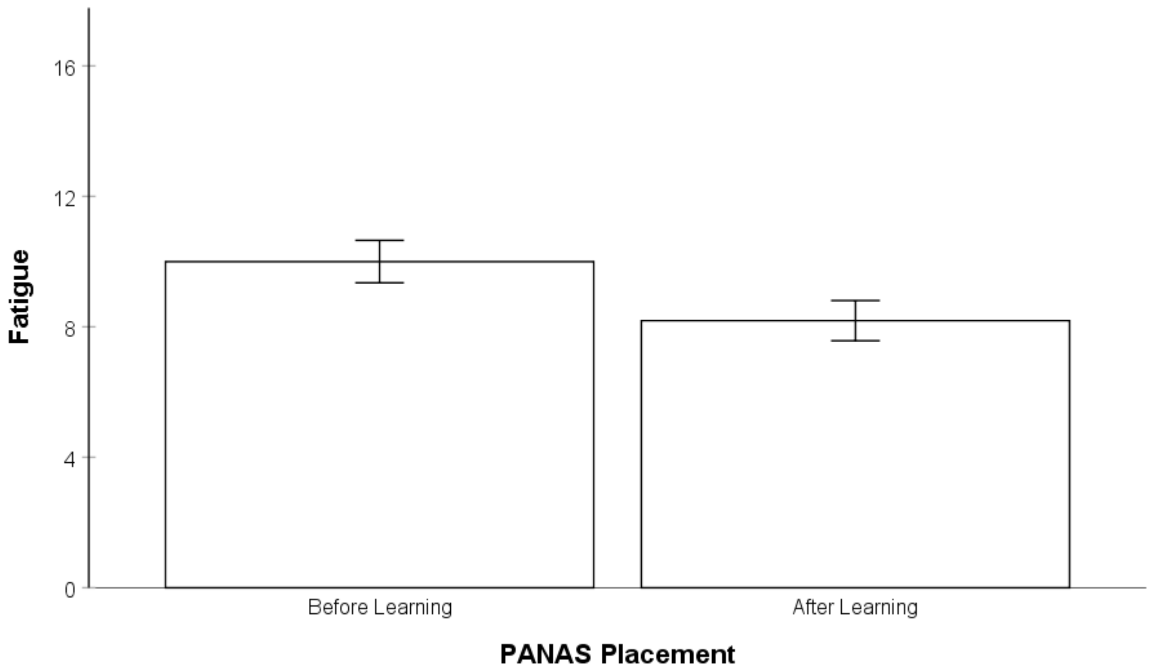

Figure 4. Self-reported fatigue measured before and after learning the Tower of Hanoi. Error bars denote one standard error around each mean.

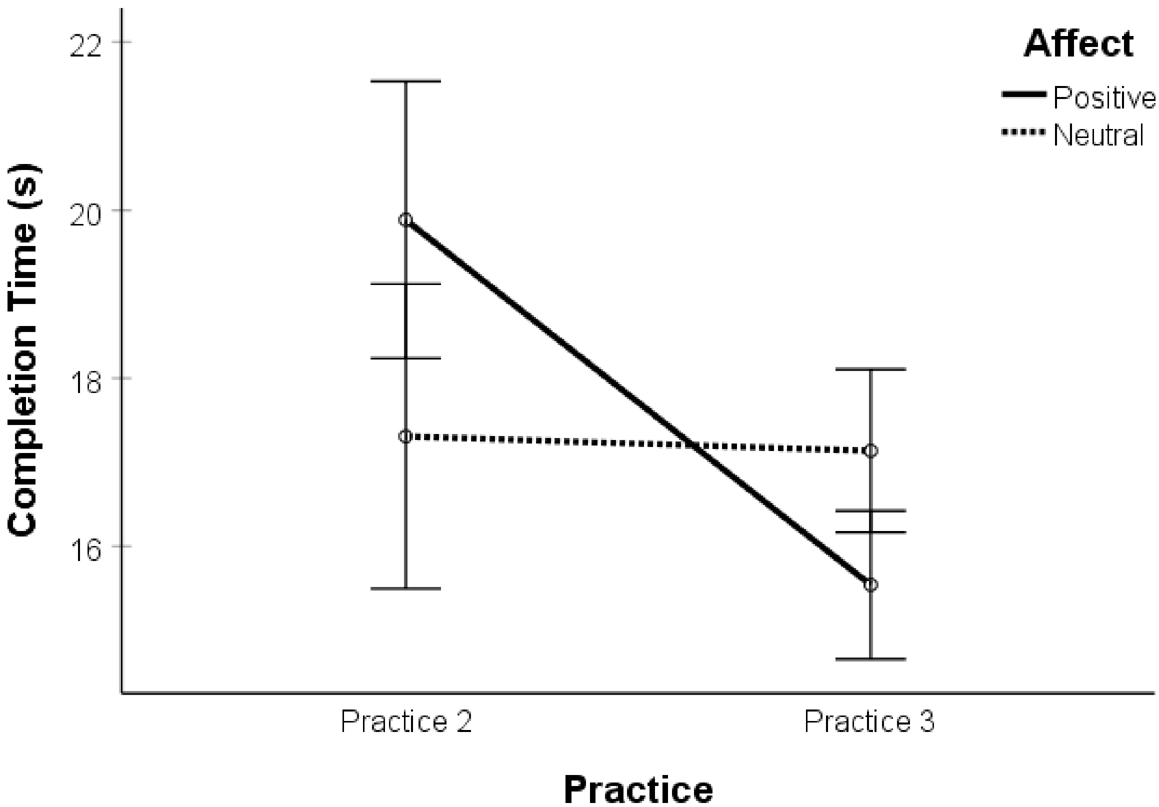

Figure 5. Practice trial completion time measured at practice two and practice three separated by affective condition. Error bars denote one standard error around each mean.

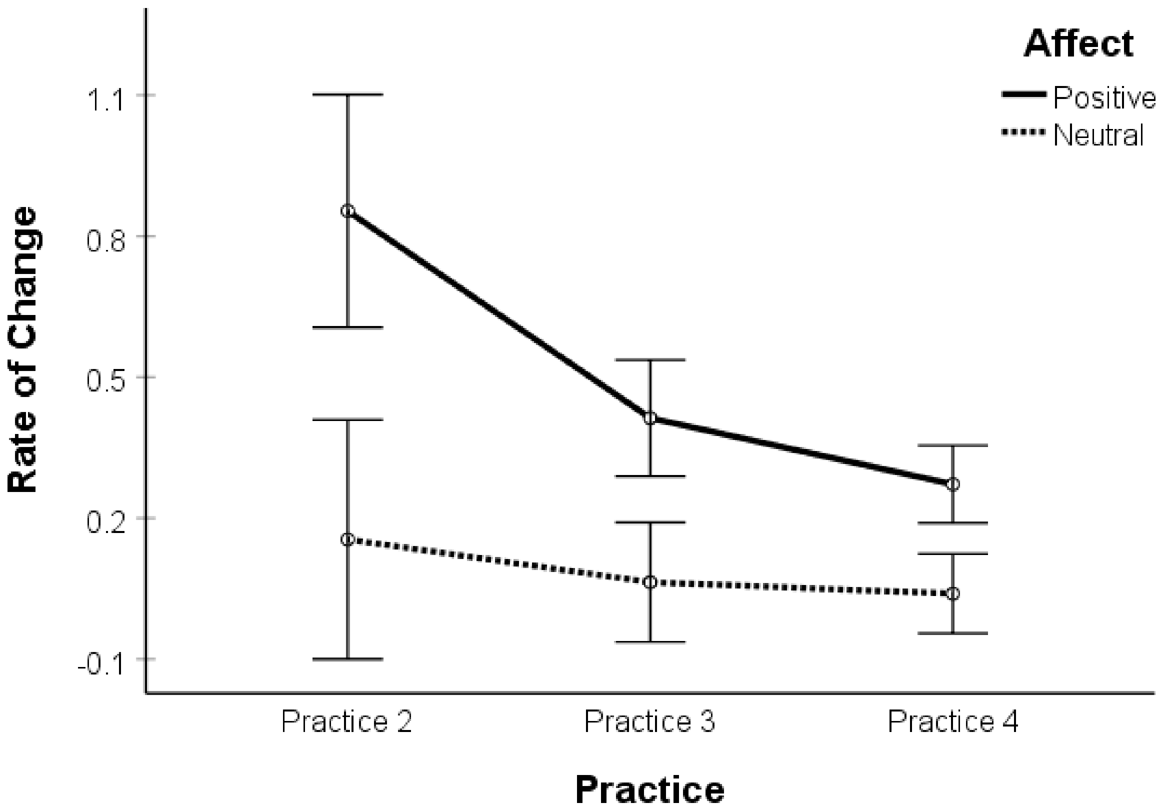

Figure 6. Rate of change in practice trial completion time at practice trial two through practice trial four separated by affective condition. Error bars denote one standard error around each mean.

Bibliography

Atkinson, R. C., & Shiffrin, R. M. (1968). Human memory: A proposed system and its Control processes. *Psychology of Learning and Motivation*, *2*, 89-195.

Baddeley, A. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences*, *4*, 417-423.

Baddeley, A. D., & Hitch, G. (1974). Working memory. In G. H. Bower, *The psychology of learning and motivation* (pp. 47-89). New York: Academic Press.

Bandura, A. (1994). Self-efficacy. In V. S. Ramachaudran, *Encyclopedia of human behavior* (Vol. 4, pp. 71-81). New York: Academic Press.

Birkholz, S. A., Hessler, E. E., & Root, M. (2016). Retroactive interference effects on procedural memory: An assessment of problem solving task performance. Unpublished manuscript.

Chun, M. M., & Turke-Browne, N. B. (2007). Interactions between attention and memory. *Current opinion in neurobiology*, *17*, 177-184. doi: 10.1016/j.conb.2007.03.005

Cohen, N. J., Eichenbaum, H., Deacedo, B. S., & Corkin, S. (1985). Different memory systems underlying acquisition of procedural and declarative knowledge. *Annals of the New York Academy of Sciences*, *444*, 54-71.

Dolan, R. J. (2002). Emotion, cognition, and behavior. *Science*, *298*, 1191-1194.

Elliot, A. J., & Covington, M. V. (2001). Approach and avoidance motivation. *Educational Psychology Review*, *13*, 73-92.

Flaisch, T., Steinhauser, M., & Schupp, H. T. (2016). Emotional aftereffects: When emotion impairs subsequent picture recognition. *Emotion*, *16*, 987-996.

Fitts, P. M. (1964). Perceptual-motor skill learning. In A. W. Melton, *Categories of human learning* (pp. 243-285). New York: Academic Press.

Krawczyk, D. C., & D'esposito, M. (2013). Modulation of working memory function by motivation through loss-aversion. *Human Brain Mapping*, *34*, 762-774. doi: 10.1002/hbm.21472

Moore, A. M., Rudig, N. O., & Ashcraft, M. H. (2014). Affect, motivation, working memory, and mathematics. *The Oxford Handbook of Numerical Cognition*, 1-16. doi: 10.1093/oxfordhb/9780199642342.013.004

Roediger, H. L. (1990). Implicit memory: Retention without remembering. *American Psychologist*, *45*, 1043-1056.

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology*, *25*, 54-67. doi: 10.1006/ceps.1999.1020.

Scoville, W. B., & Milner, B. (1957). Loss of recent memory after bilateral hippocampal lesions. *Journal of Neurology, Neurosurgery & Psychiatry*, *20*, 11-21.

Squire, L. R. (1986). Memory and the brain. In K. A. Klivington, S. L. Friedman, & R. W. Peterson, *The Brain, Cognition, and Education* (pp. 171-202). Orlando: Academic Press Inc.

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science*, *12*, 257-285.

Watson, D., & Clark, L. A. (1999). The PANAS-X: Manual for the positive and negative affect schedule - expanded form.

Xu, Y., & Corkin, S. (2001). HM revisits the Tower of Hanoi Puzzle. *Neuropsychology*, *15*, 69.

Yang, H., Yang, S., & Isen, A. M. (2013). Positive affect improves working memory: Implications for controlled cognitive processing. *Cognition and Emotion*, *27*, 474-482.

Zhang, X., Yu, H. W., & Barrett, L. F. (2014). How does this make you feel? A comparison of four affect induction procedures. *Frontiers in Psychology*. *5*, 1-10. doi: 10.3389/fpsyg.2014.00689.

Appendix A

PANAS-x

This scale consists of a number of words and phrases that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. Indicate <u>to what extent you have felt this way during the past few moments</u>. Use the following scale to record your answers:

1	2	3	4	5
very slightly or not at all	a little	moderately	quite a bit	extremely

______ cheerful	______ sad	______ active	______ angry at self
______ disgusted	______ calm	______ guilty	______ enthusiastic
______ attentive	______ afraid	______ joyful	______ downhearted
______ bashful	______ tired	______ nervous	______ sheepish
______ sluggish	______ amazed	______ lonely	______ distressed
______ daring	______ shaky	______ sleepy	______ blameworthy
______ surprised	______ happy	______ excited	______ determined
______ strong	______ timid	______ hostile	______ frightened
______ scornful	______ alone	______ proud	______ astonished
______ relaxed	______ alert	______ jittery	______ interested
______ irritable	______ upset	______ lively	______ loathing
______ delighted	______ angry	______ ashamed	______ confident
______ inspired	______ bold	______ at ease	______ energetic
______ fearless	______ blue	______ scared	______ concentrating
______ disgusted with self	______ shy	______ drowsy	______ dissatisfied with self

Participant Information Survey

1. Check the box here if you do not wish to provide some or all of the below information.

❑

---

2. What is your age in years? __________

3. What is your biological sex? (circle one) **Female** **Male**

4. What is your year in college? (circle one) **Freshman** **Sophomore** **Junior** **Senior**

5. What race do you consider yourself to be? (check all that apply)

❑ **American Indian or Alaska Native** (A person having origins in any of the original peoples of North, Central, or South America and who maintains tribal affiliation or community attachment.)

❑ **Asian** (A person having origins in any of the original peoples of the Far East, Southeast Asia, Pacific Islands, or the Indian subcontinent.)

❑ **Black or African American** (A person having origins in any of the black racial groups of Africa.)

❑ **White** (A person having origins in any of the original peoples of Europe, the Middle East, or North Africa.)

6. Do you consider yourself to be Hispanic or Latino?

❑ **Hispanic or Latino** (A person of Mexican, Puerto Rican, Cuban, South or Central American, or other Spanish culture or origin, regardless of race.)

❑ **Not Hispanic or Latino**

7. What is your dominant hand? (circle one) **Right** **Left** **Ambidextrous**

8. Do you currently play a musical instrument? (circle one) **No** **Yes**

9. If you answered yes above, what instrument(s) do you play? (list up to 3)

____________________ ____________________ ____________________

10. Have you had any experience with the Tower of Hanoi puzzle before today? **Yes** **No**

11. Did receiving the $10.00 Amazon.com gift card make you feel happier? **Yes** **No**

12. Did you know about the $10.00 Amazon.com gift card before the experiment **Yes** **No**